Domains, Knowledge Structures, and Integration Strategies

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Abstract

A central issue in cognitive science is whether learning and processing constraints are particular to domains or whether they generalize across domains. In this paper the domain-generality of a particular type of constraint, linear separability, was examined. Prior research has found that decisions in the social domain are often consistent with linear separability but this is rarely true of decisions in the object domain. Two experiments were conducted to examine the generality of this result by using fundamentally different types of social and object materials than have been used in previous research. In both experiments different integration strategies were observed in social and object domains, and as in prior research many more Summation sorts occurred with social materials. These results indicate that previous differences that have been observed between object and social domains generalize to very different types of object and social materials. At a general level the results indicate that the structure of knowledge varies with domain, and consequently it will be difficult to formulate domain-general constraints in terms of abstract structural properties such as linear separability.

Introduction

A central issue in cognitive science concerns the domain-generality of learning and processing constraints. Are learning and processing constraints particular to domains or do they generalize across domains? The research in this article investigated the extent to which linear separability constrained categorization decisions in different content domains. Linear separability is a principle that is relevant to categorization processes (e.g. Medin & Schwanenflugel, 1981; Waldmann & Holyoak, 1990; Wattenmaker, Dewey, Murphy, & Medin, 1986), connectionist modeling (e.g., Gluck & Bower, 1988), and machine learning (Nilsson, 1965). In relation to categorization, linearly separable categories are categories that can be partitioned on the basis of a weighted, additive combination of component information.

In a series of experiments, Wattenmaker (in press) found that linear separability was a much more important constraint on decisions in the social than the object domain. It was concluded that different knowledge structures were activated in social and object domains, and that these differences in knowledge structures produced differences in encoding and integration strategies. The integration strategies that were activated in the social domain were compatible with linear separability, but the strategies that were activated in the object domain were inconsistent with linear separability. Thus, this research indicated that the naturalness of abstract structures and principles such as linear separability will vary with content domain.

The present research was designed to test the generality of these results. This was accomplished by using different social materials and different object materials than were used in the Wattenmaker (in press) studies. Indeed, there are many different types of social and object concepts, and within the social and the object domains concepts have very different structures. Thus, it is possible that the compatibility between the social domain and linear separability and the incompatibility between the object domain and linear separability might be limited to a sub-set of concepts within each of these domains.

Experiment 1

In the Wattenmaker (in press) studies, the social categories were either traits (extroverted, cautious, etc.) or occupations (lawyer, doctor, etc.). In this experiment we attempted to use social materials that had a very different structure. To accomplish this we used social events as the social categories. Event categories such as *political rally* seem to be less abstract than trait categories such as *extrovert*, and the flexibility in interpretation that characterizes the processing of traits and behaviors seems to be greatly reduced with social events. Flexibility in interpretation and reliance on abstract representations rather than exemplars seem to be important factors for producing compatibility with linearly separable structures (see Wattenmaker, in press). Thus, the structure of social events might be much less compatible with linear separability.

To investigate this possibility, participants were presented with descriptions of social events or descriptions of objects, and they were asked to divide the examples into two equal-sized groups. Four pairs of social event categories and four pairs of object categories were used in the experiment. These categories are listed in Table 2. As an illustration of the features that were used, the *rock concert* vs. *poetry reading* events were represented by the following features: *the audience was large* vs. *the audience was small*; *many members of the audience were intoxicated* vs. *few members of the audience were intoxicated; several people at the event were rude vs. most people at the event were polite*; and *the atmosphere for the event was jovial* vs. *the atmosphere for the event was serious*. The first of each of these pairs was associated with a *rock concert* and the second with a *poetry reading*. As an illustration of the object categories, the *bird* vs. *not bird* object categories were represented by the features: *flies* vs. *does not fly*, *is light in weight* vs. *is heavy in weight*; *eats worms and insects* vs. *does not eat worms and insects*; and *builds a nest in a tree* vs. *does not build a nest in a tree*. The first of each of these features was associated with the bird category.

The social and object descriptions were constructed from the same underlying structure (represented by the abstract notation in Table 1), but this structure was represented by object or social characteristics. Consider, for example, the social task in which the relevant categories were *rock concert* vs. *poetry reading*. Each of the four contrasting features listed above was randomly assigned to one of the dimensions in Table 1 (e.g., the contrast between a *large* vs. *a small audience* might be assigned to D1), and the 1's in Table 1 were represented by features of a rock concert whereas the 0's were represented by features of a poetry reading. Thus, for one randomization, Exemplar 1 (1110) in Table 1 was represented as *the audience was large*, *many members of the audience were intoxicated*, *several people at the event were rude*, and *the atmosphere for the event was serious*; Exemplar 2 (1101) was represented as *the audience was large, many members of the audience were intoxicated, most people at the event were polite*, and *the atmosphere for the event was jovial*. Thus, in this condition the four examples on the left side of Table 1 had three features that were typical of a rock concert and only one feature that was typical of a poetry reading. Alternatively, the four examples on the right side of Table 1 had three features that were typical of a poetry reading and only one feature that was typical of a rock concert. The examples for the other three pairs of social event categories (listed in Table 2) were also constructed from Table 1 using this same procedure except that different features were used.

Table 1: Abstract representation of the linearly separable categories used in Experiments 1 and 2.

LINEARLY SEPARABLE CATEGORIES

Category A					Category B				
	Dimension					Dimension			
Exemplar	D1	D2	D3	D4	Exemplar	D1	D2	D3	D4
A1	1	1	1	0	B1	0	0	0	1
A2	1	1	0	1	B2	0	0	1	0
A3	1	0	1	1	B3	0	1	0	0
A4	0	1	1	1	B4	1	0	0	0

For the object materials the 1's and 0's in Table 1 were represented by the features that were used to represent the object materials. For example, in the *bird* vs. *not bird* condition, Exemplar 1 (1110) was *flies*, *light in weight*, *eats worms and insects*, and *does not build a nest in a tree*; Exemplar 2 (1101) was *flies*, *light in weight*, *does not eat worms and insects*, and *builds a nest in a tree*. Thus, in this condition each example on the left side of Table 1 had three features that were typical of a bird and only one feature that was not typical of a bird. Alternatively, each example on the right side of Table 1 had three features that were not typical of a bird and only one feature that was typical of a bird. The examples for the other three pairs of object categories (listed in Table 2) were also constructed from Table 1 using this same procedure.

For the social task participants were presented with 8 descriptions that were constructed from Table 1 using the procedure described above. The eight descriptions were constructed from either the *rock concert/poetry reading* features, the *elevator/bar* features, the *football game/opera* features, or from the *political rally/movie* features. Each subject received the descriptions from one of these category pairs. Likewise, for the object task participants were presented with 8 descriptions that were also constructed from Table 1. The eight descriptions were constructed from either the *bird/non-bird* features, the *animal/furniture* features, the *screwdriver/hammer* features, or the *airplane/car* features.

In the object and the social task participants were given the relevant category labels (e.g. *rock concert* vs. *poetry reading* labels) and asked to place four of the eight descriptions in one of the categories and the other four descriptions in the other category. Thus, in the *rock concert* vs. *poetry reading* condition, participants were asked to place four of the descriptions in the *rock concert* category and four of the descriptions in the *poetry reading* category. Likewise, in the *bird* vs. *non-bird* condition, participants were asked to place four of the descriptions in the *bird* category and four of the descriptions in the *non-bird* category.

There are many possible ways to partition the examples represented in Table 1. If a strategy of summing characteristic features is natural, however, then Exemplars 1-4 would be placed in one category and Exemplars 5-8 would be placed in the other category. That is, Exemplars 1-4 all have three features that were typical of one of the categories (e.g. *rock concert*) whereas Exemplars 5-8 all have three features that were typical of the other category (e.g. *poetry reading*). Thus, if subjects adopt a strategy of summing the number of typical features, then Exemplars 1-4 will be placed in one category and Exemplars 5-8 will be placed in the other category. These categories would be linearly separable, and they would also be consistent with family resemblance and prototype notions. This particular pattern of sorting will be called a Summation sort.

In prior experiments that used trait and occupation categories as social materials, many more Summation sorts were observed in the social than the object domain (Wattenmaker, in press). If these results generalize to other types of categories within the social domain, then there should be more Summation sorts for the social event materials than for the object materials.

Method

Each subject performed a social sort and an object sort. The first sort for half of the subjects was a social sort and the first sort for the other subjects was an object sort. Fifty subjects participated in the experiment. All the features that were used in the experiment were rated to be clearly associated with the correct category (e.g., *most people at the event were polite* was rated to be highly characteristic of *poetry reading*). All other aspects of the procedure were detailed above.

Results and Discussion

As indicated in Table 2, many more Summation sorts occurred with the social materials than the object materials (.48 vs. .12). A sign test indicated that this difference was highly significant ($p < .01$). Table 2 reveals that there were large differences in the number of Summation sorts that occurred with the different social categories. Future work will be designed to examine exactly what was responsible for these differences. However, all four of the social sorts produced more Summation sorts than the object condition that had the highest number of Summation sorts (i.e., the *bird* vs. *non-bird* condition), and in almost all cases these differences were very large. Thus, the differences between the objects and social event categories appear to be very reliable.

Table 2: Results of Experiment 1.

Social Events	Percentage of Summation Sorts
elevator/bar	.42
football game/opera	.54
rock concert/poetry reading	.29
political rally/movie	.73
Average for social events	.48
Objects	
animal/furniture	.15
screwdriver/hammer	.07
bird/non-bird	.18
airplane/car	.08
Average for objects	.12

These results clearly indicate that even when social events are used as social materials people are more likely to sum features and form linearly separable categories in the social than the object domain. Thus the compatibility between linear separability and the social domain extends to many different types of social categories, and appears to represent a highly general domain effect.

Experiment 2

Whereas Experiment 1 used different social materials than had been used in previous research, in this experiment we attempted to use very different types of object materials. Specifically, in Experiment 1 and in all of the experiments reported in Wattenmaker (in press), the object categories were very familiar (*birds*, *furniture*, *hammers*, *cars*, etc.). These types of object categories are not only very familiar, but they also represent fairly stable categories, they are clearly defined, and have many accessible exemplars. In contrast, social terms such as *extroverted* or *cautious* can be viewed as less stable, less structured, and to be more abstract. Thus, in this experiment we attempted to design object categories that were less familiar, that did not have a clear structure, were more abstract, and in general, seemed to be more similar to trait categories. To accomplish this, we used object categories that could be viewed as characteristics rather than stable categories. For example, in one case the object categories were *fragile* vs. *not fragile*. It is clearly possible to classify an object as fragile or not, but in relation to concepts such as bird and hammer, fragile does not seem to represent a stable, familiar, and clearly defined category. Indeed object categories of this type can be viewed as more parallel in structure to trait concepts. The complete set of object and social categories that were used in this experiment are shown in Table 3.

As an illustration of the descriptions that were used for the object categories, the features for the *fragile* vs. *not fragile* categories were: *made of glass* vs. *made of plastic*; *thin sides* vs. *thick sides*; *very light weight* vs. *medium weight*; and *very old* vs. *new*. The first of each of these features was associated with the *fragile* category. The object and social sorts were again constructed from Table 1, using the procedure described in Experiment 1.

These more abstract and less structured object categories might greatly increase the frequency of Summation sorts for object materials. If the differences that have been observed between object and social materials in previous research are attributable to the use of very familiar object categories, then an equal number of Summation sorts should be observed with the social and object materials. Alternatively, if the observed differences between object and social domains are highly general, then we should find more Summation sorts with the social than the object materials.

Method

Each subject performed four sorts: two object and two social sorts. Half of the subjects did a social sort, an object sort, a social sort, and finally an object sort; this order was reversed for the other subjects. A total of 96 subjects participated in this experiment. As in Experiment 1, the features that were used to represent the categories were rated to be clearly associated with the correct category. All other aspects of the procedure were identical to Experiment 1.

Results and Discussion

The percentages for the social categories shown in Table 3 represent the percentages of Summation sorts that occurred when the social sort was the first sort a subject performed. Likewise, the percentages for the object categories represent the percentages of Summation sorts that occurred when the object sort was the first sort a subject performed. When the results of the first, second, third, and fourth sorts were included, then overall 80% of the social sorts were

Summation sorts and 54% of the object sorts were Summation sorts. A sign test indicated that this difference was highly significant ($p < .01$). Thus, even when very different object categories were used many more Summation sorts were again observed with social materials.

Table 3: Results of Experiment 2.

Social Categories	Percentage of Summation Sorts from the first sort
cautious/not cautious	.83
energetic/not energetic	.83
extroverted/not extroverted	.83
Average of first social sort	.83
Object Categories	
dangerous to handle/not dangerous to handle	.50
fragile/not fragile	.17
valuable/not valuable	.67
Average of first object sort	.45

Table 3 reveals that there were large differences in the number of Summation sorts that occurred with the different object categories. Future work will be designed to examine exactly what was responsible for these differences. However, all three of the social sorts produced more Summation sorts than the object condition that had the highest number of Summation sorts (i.e., the *valuable* vs. *not-valuable* categories). Thus, the differences between the object and social categories appear to be very reliable.

General Discussion

In both experiments many more Summation sorts were observed with social materials than object materials. This occurred even though the social categories in Experiment 1 were selected to be incompatible with a summation strategy and linear separability, and the object categories in Experiment 2 were selected to be especially compatible with a summation strategy and linear separability. These results are consistent with the Wattenmaker (in press) results. In the Wattenmaker (in press) experiments, across seven sorting experiments a total of 201 Summation sorts occurred with social materials whereas only 97 Summation sorts occurred with object materials. In combination with the present results, these results suggest that the differences between the object and social domains are highly general.

These differences between the object and social domains seem to reflect basic differences in the structure and nature of the domains. Objects are concrete, highly structured entities that are characterized by many different types of relational properties. In contrast, social concepts are abstract and the structure and organization of social concepts is less clear. Instead of representing concrete entities, social concepts are frequently based on interpretations, inferences, and constructions rather than direct or unambiguous perceptions. These basic differences in object and social domains appear to produce many differences in the structure of knowledge and in categorization processes. At a general level the results are consistent with the idea that background or world knowledge will have important influences on concept learning (e.g. Murphy & Medin, 1985; Waldmann & Holyoak, 1990; Wattenmaker, et al, 1986).

A clear implication of these results is that the naturalness or learnability of abstract structures will vary with domain. The structure of knowledge appears to vary with domain, and consequently abstract structures or principles such as linear separability will be more important in some domains than others.

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